PWD Preliminary Review of Sturgeon and DO Data for the Delaware and Hudson Rivers

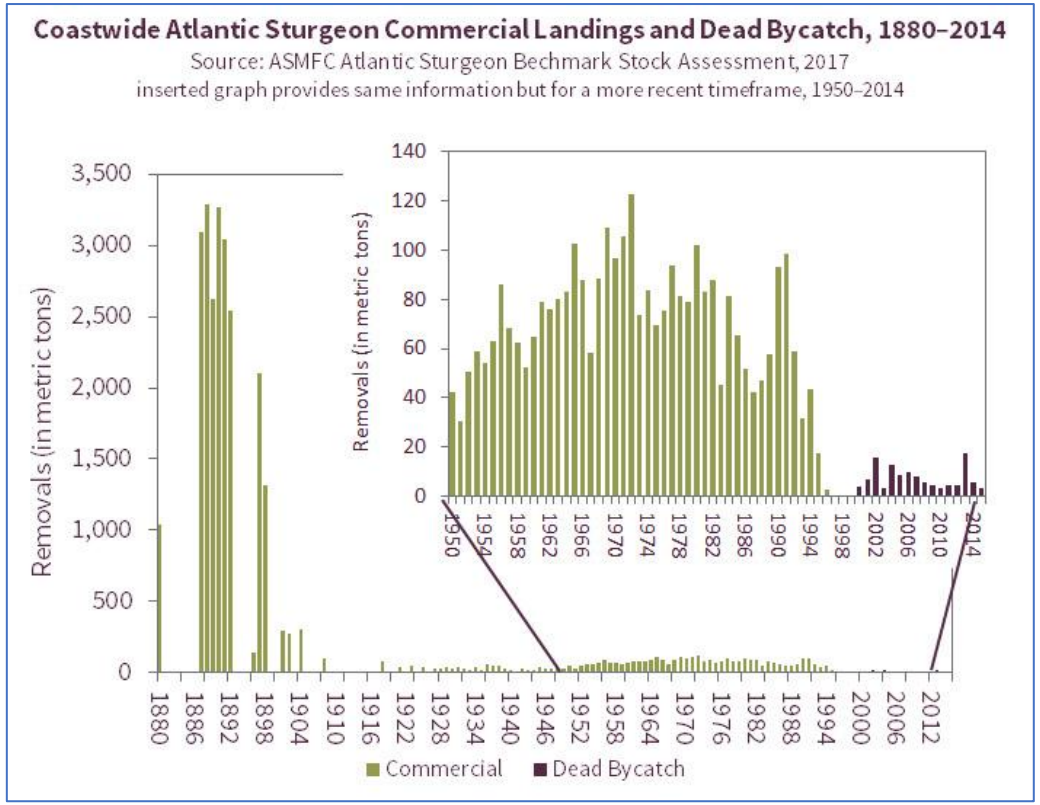
Water Resources Association of the Delaware River Basin
March 14, 2023

PHILADELPHIA WATER DEPARTMENT

Background

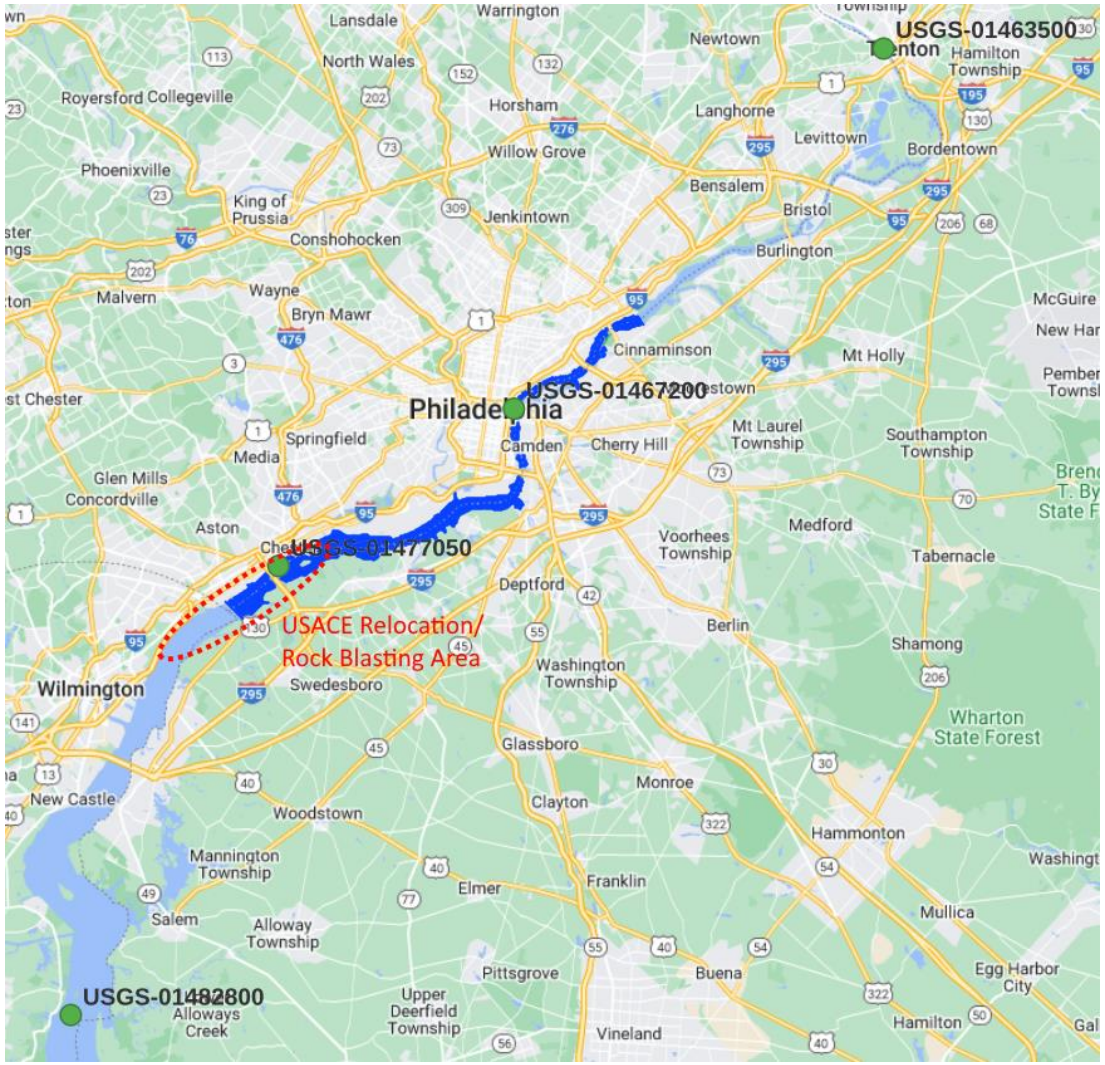
- Atlantic sturgeon identified as key sensitive species in Del. Estuary
- Long-lived, slow-maturing anadromous species
- Overfished in 19th century
- 1998 harvest moratorium
- 2012 Listed as Endangered
- Focal point for advocacy and potential policy-making

ASMFC 2013



Background

- DRBC conducting Aquatic Life Use attainability study (Res. 2017-04)
- Evaluate “propagation” of fish and dissolved oxygen (DO) in Zones 3 & 4 of Delaware estuary (currently “maintenance”)
- PWD and other municipal dischargers would be most affected by rulemaking to reduce ammonia and increase DO



Background

- PWD reviewed reports/sources in DRBC use attainability study
  - Primary literature from laboratory studies, including studies cited in DRBC in Linking Aquatic Life Uses with DO Conditions in the Delaware River Estuary
- Lack of consensus on DO needs of sensitive species as well as relative importance of intrinsic, environmental, and anthropogenic factors contributing to slow rate of recovery of sturgeon
- PWD review concluded that sturgeon monitoring data were underutilized and not publicly available
- **Data** and **facts** are important to the public and regulated community

  1.) Ensure that proposed policy changes are based on sound science

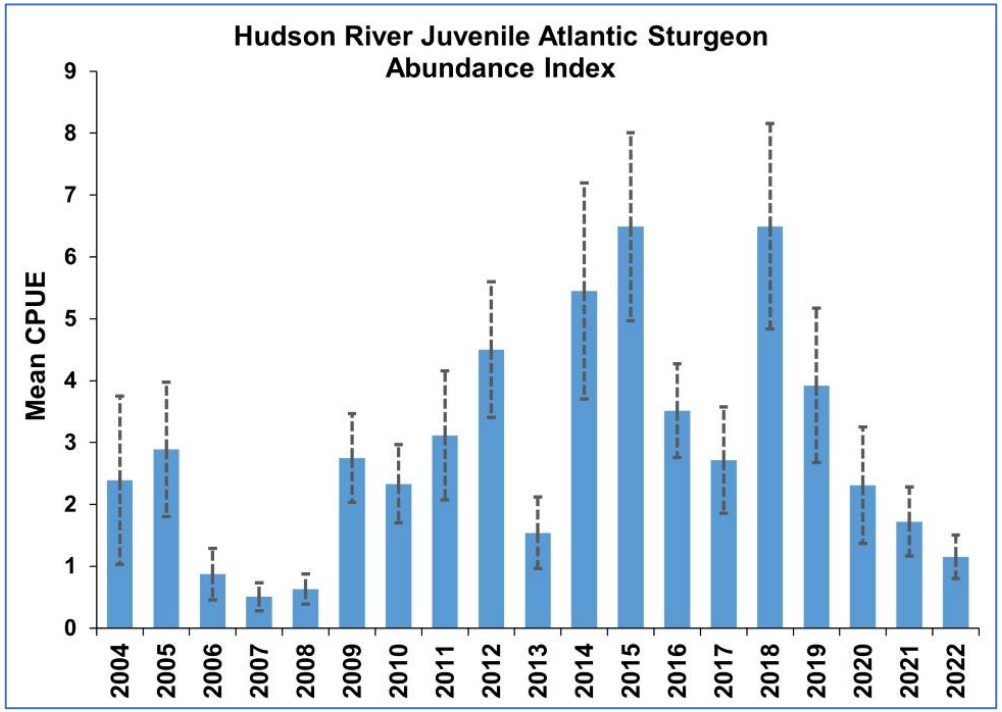
  2.) Establish baseline information from which goals can be defined and future success measured

Background

- PWD acknowledges that stakeholders may have different interpretations of observed sturgeon and DO data. This presentation primarily addresses data availability, not firm conclusions from the data
- PWD recognizes the expertise of state/federal fisheries resource agencies and academic researchers. I'm not a fisheries biologist.
- DO-fish interaction analysis will benefit from multi-disciplinary expertise (water quality, fish life history, statistics)
- Goal – Fully utilize available DO and fish data sets
  1. Avoid duplication of effort
  2. Address any concerns regarding publication value or ESA

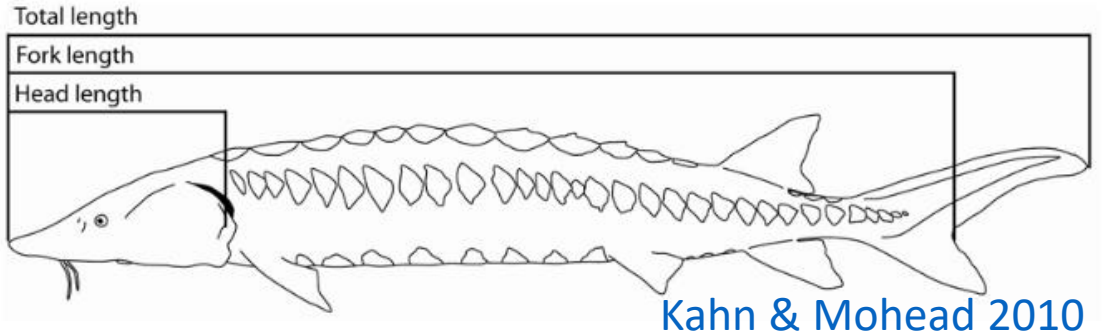
Background

- Spawning success difficult to measure
- Many species exhibit high inter-annual variability, even in “natural” systems
- Catch Per Unit Effort (CPUE) indices
- Hypoxia is believed to be more stressful to early life stages, which tend to be restricted to their natal river by salinity
- Growth of juveniles may be useful as indicator of sublethal effects of hypoxia in Delaware estuary



Background

- **Tag-recaptures** enable empirical growth rate measurements
- Weight-Length relation (*i.e.*, **fish "condition"**) for individual specimens
- **W-L regression model parameters** in years w/ adequate data



Kahn & Mohead 2010


NYSDEC 2023

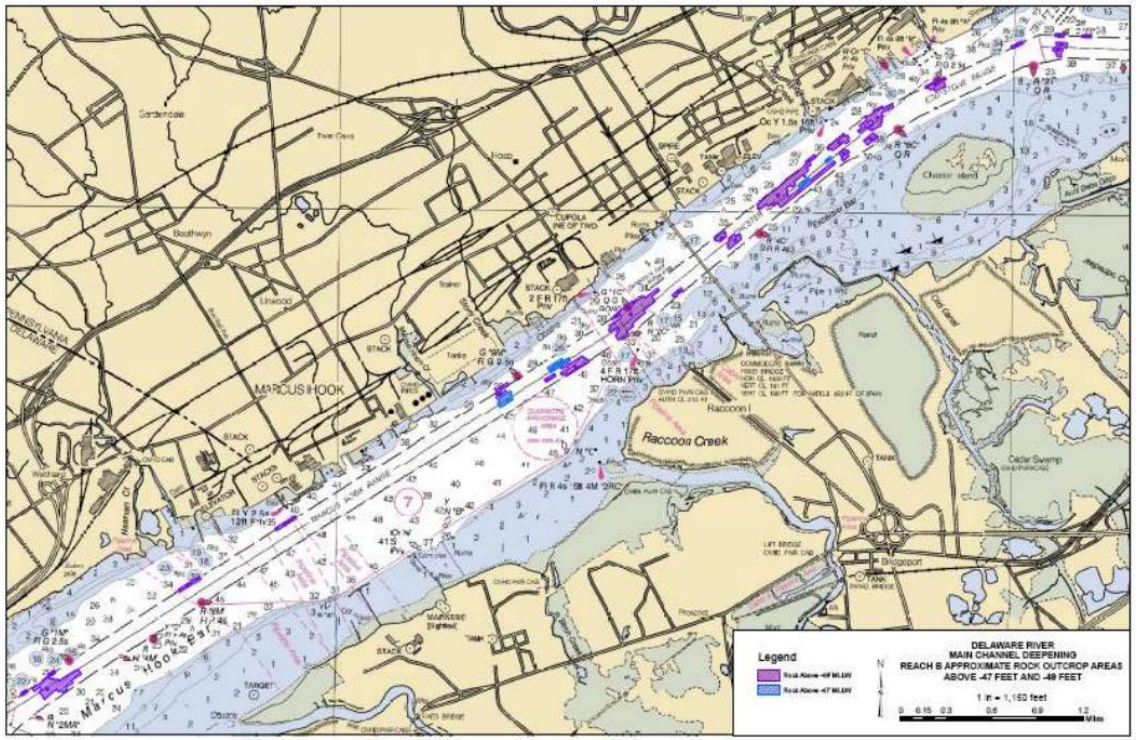
- PWD recommends using multiple lines of evidence to evaluate the relative importance of hypoxia to juveniles as a stressor on overall sturgeon recovery; Consider evidence from outside the case (EPA CADDIS step 4), such as Hudson River, other DPS (*e.g.*, James R.)

DNREC Monitoring

- Long running program; sampling locations and gears fished have varied
- Recent sampling adequately captures juveniles relevant for DO analysis
- Juvenile CPUE index being developed (15 years of data needed)
- NOAA Section 6 Species Recovery Grants NAIONMF4720030 (2010-2015), NA16NMF4720072 (2016-2020)
  - Final Report “Sturgeons in the Mid-Atlantic Region: A Multi-State Collaboration of Research and Conservation” (DNREC 2015)
  - Final Report “Conservation and Recovery of Juvenile Sturgeons in the Delaware River” (Park 2020)
- Annual variability in spawning (CPUE) vs. various measures of DO has been used for advocacy purposes by TNC and Riverkeeper
- DNREC provided raw data 2014-2019, earlier data transcribed from PDFs

ERC Relocation Trawling Reports

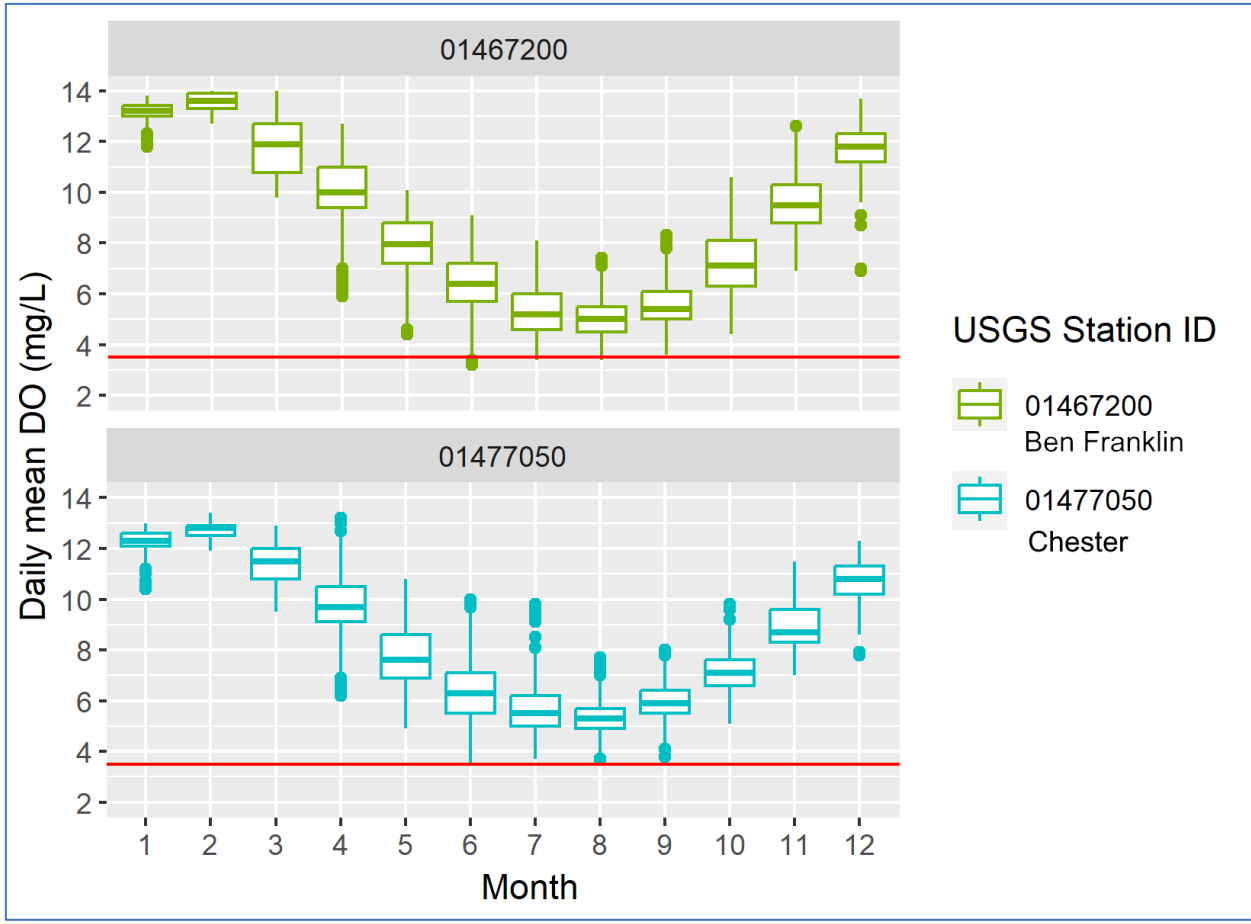
- ERC Contracted for USACE Delaware Main Channel Deepening Project
- 2014 Relocation Feasibility Report
- Relocation Trawling Reports 2016-2019
- Trawling conducted late winter/early spring; mostly YOY & juvenile captures
- Numerous project re-captures and DNREC-tagged recaptures
- Raw data transcribed from PDF files



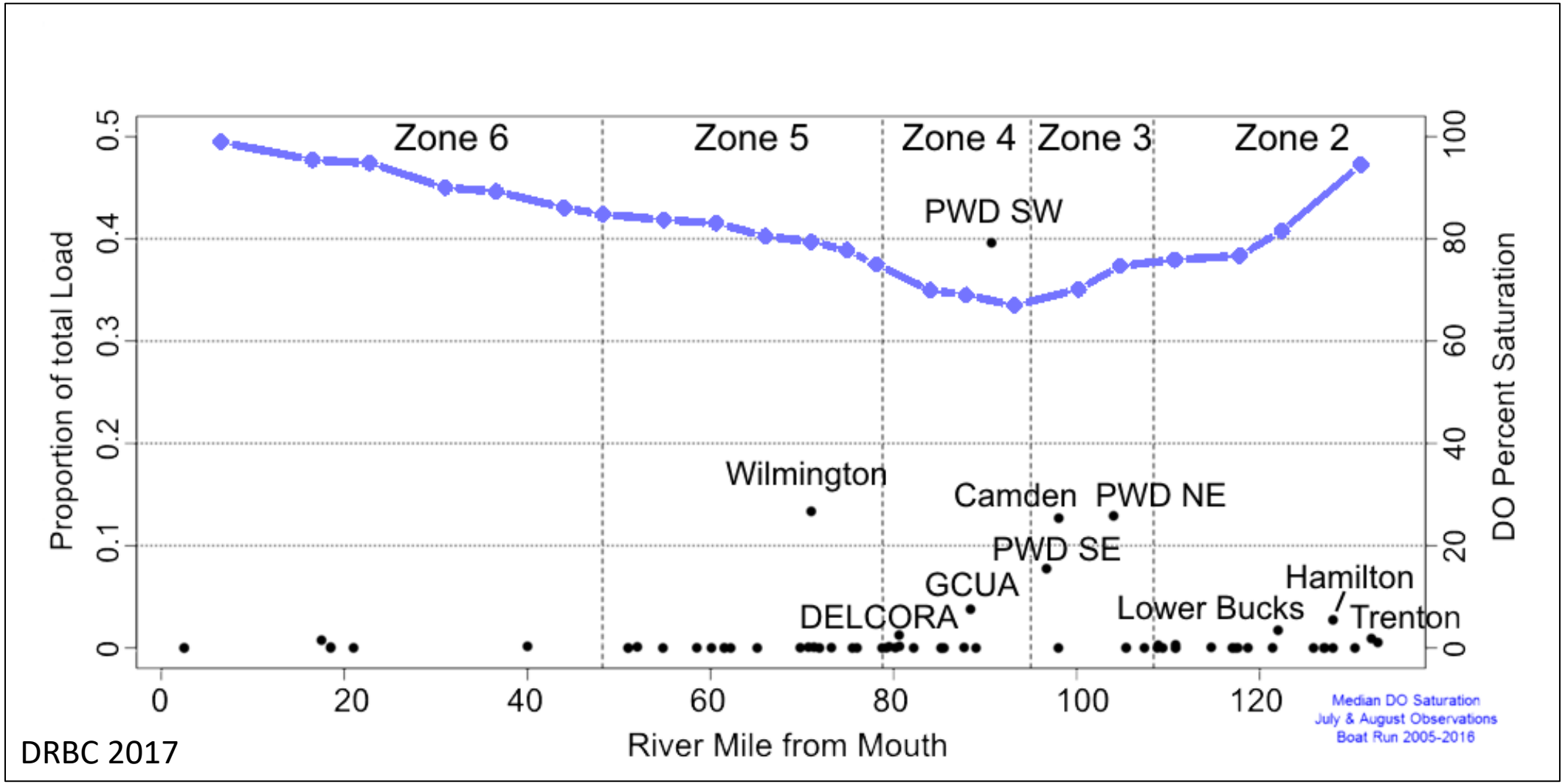
Delaware River Main Channel Deepening Reach B Approximate Rock Outcrop areas (USACE figure in ERC 2016 Report)

Delaware River DO Monitoring

- USGS Continuous Water Quality Monitoring Stations
  - Trenton (01463500) RM 134.5
  - **Ben Franklin/ISM (01467200) RM 100.1**
  - **Chester (01477050) RM 83.6**
  - Reedy Island (01482800) RM 54.1
- Daily DO and temp data 2000-2021
- 2012 selected as critical condition by DRBC for WQ model corroboration
- Chester gage closest to spawning area



Delaware River DO Monitoring



DRBC 2017

Hudson River Sturgeon & DO Monitoring

- Hudson River is believed to have the largest extant population of Atlantic sturgeon in the New York Bight DPS.
- Hudson DO levels consistently higher than those in the urban Delaware River during the growing season/critical DO period
- NYSDEC gillnet survey data obtained via FOIL request to NYSDEC
- Hudson River Biological Monitoring Program (funded by Hudson R. electrical generators) data obtained from NOAA via FOIA request
- Hudson River Environmental Conditions Observing System (HRECOS) multi-agency collaboration to collect environmental data incl. DO
- PWD obtained historical DO data (Excel) from HRECOS website

DO Data Processing

- DO statistics computed using USGS daily value (DV) and instantaneous unit value (UV) data
  - Growing Season - May-Oct
  - Critical Period - Jul-Sept
- PWD strongly recommends evaluating hypoxia as DO percent saturation
  - Adverse physiological effects of hypoxia are caused by low DO saturation (difference in partial pressures). While hypoxic effects can be exacerbated at higher temperatures due to higher metabolic demand, DO concentration does not necessarily accurately model these effects

Delaware Atlantic Sturgeon Data Summary

- DNREC provided Excel file of raw data for 2016-2019 NOAA grant
  - 434 raw Atlantic sturgeon records, most from 2017 & 2018*
- ERC data transcribed from five reports (2014, 2016, 2017, 2018, 2019)
  - 5042 raw records*
- Both data sets included total length, fork length, weight, and PIT tag ID

Year	2014	2015	2016	2017	2018	2019	Total
ERC*	37	482	573	1863	728	1359	**5042**
DNREC*	NA	NA	13	163	240	18	**434**
Total Atlantic sturgeon*	37	482	586	2026	968	1377	**5476**

* Totals show **data availability only**, not intended to reflect interannual differences in abundance

Additional Delaware Sturgeon Data

- PWD compiled additional data from Delaware River publications, many lack adequate number of juvenile samples for W-L or DO analysis

Publication	n	Total length	Fork length	weight	PIT Tag ID
Lazzari *et al*. 1986[1]	20	Yes	Yes	Yes	No
Brundage 2009[2]	6	Yes	Yes	Yes	No
Calvo *et al*. 2010[3]	53	Yes	Yes	Yes	No
Fisher *et al*. 2011[4]	46	Yes	Yes	No	Yes
ASMFC 2013[5]	54	Yes	Yes	Yes	Yes
DNREC 2015[6]	138	Yes	Yes	Yes	Yes

1. Lazzari *et al*., 1986 Occurrence of Juvenile Atlantic Sturgeon, Acipenser oxyrhynchus, in the Upper Tidal Delaware River
2. Brundage 2009, Investigations of Juvenile Shortnose and Atlantic Sturgeons in the Lower Tidal Delaware River
3. Calvo *et al*. 2010, Effects of Flow Dynamics, Salinity, and Water Quality on the Atlantic Sturgeon, the Shortnose Sturgeon and the Eastern Oyster in the Oligohaline Zone of the Delaware Estuary. *Final Report to USACE, Philadelphia District*.
4. Fisher *et al*. 2011, Atlantic Sturgeon Final Report State Wildlife Grant Project T-4-1 Period covered: October 1, 2006 to October 15, 2010
5. ASMFC 2013, ASMFC Sturgeon Management Board Meeting Minutes May 23, 2013 (Tables 3 & 4)
6. DNREC 2015, Final Report Section 6 Species Recovery Grants Program Award Number: NAIONMZF4720030 Report period: 06/01/2010 - 05/31/2015 (Tables 2.1, 2.2, Appendix A Table 5)

Hudson R. Sturgeon Data Summary

- NYSDEC Gillnet Juvenile Relative Abundance Survey 2003-2022
  - 5372 raw Atlantic & shortnose sturgeon records
    - 4448 Atlantic sturgeon, 779 Shortnose sturgeon
    - PWD QA/QC non-outlier records with total length (and/or fork length), weight, PIT tag ID
- Hudson River Generators data 2001-2020 transcribed from Excel workbooks and PDF reports prepared by Normandeau Associates.
  - 1330 raw Atlantic & shortnose sturgeon records
    - 636 Atlantic sturgeon, 540 Shortnose sturgeon PWD QA/QC non-outlier records

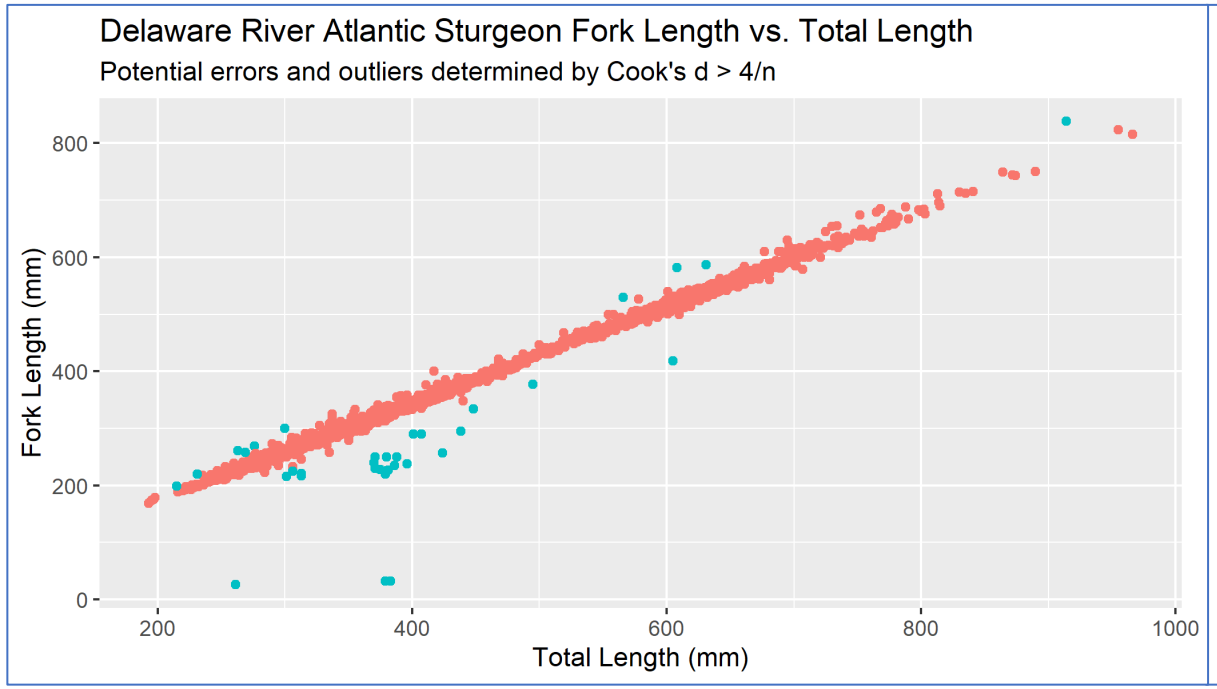
Agency	species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	**Total**
NYSDEC	Atlantic	118	190	232	69	38	64	193	191	159	242	115	337	541	359	332	572	330	98	161	107	**4448**
	shortnose	45	78	87	50	29	49	57	37	50	17	32	38	50	20	27	25	26	16	32	14	**779**
HRG	Atlantic					32	25	31	27	29	74	91	69	46	101	31	16	38	26			**636**
	shortnose	40	45	44	40	36	28	17	42		20	59	28	36	29	22	15	25	14			**540**

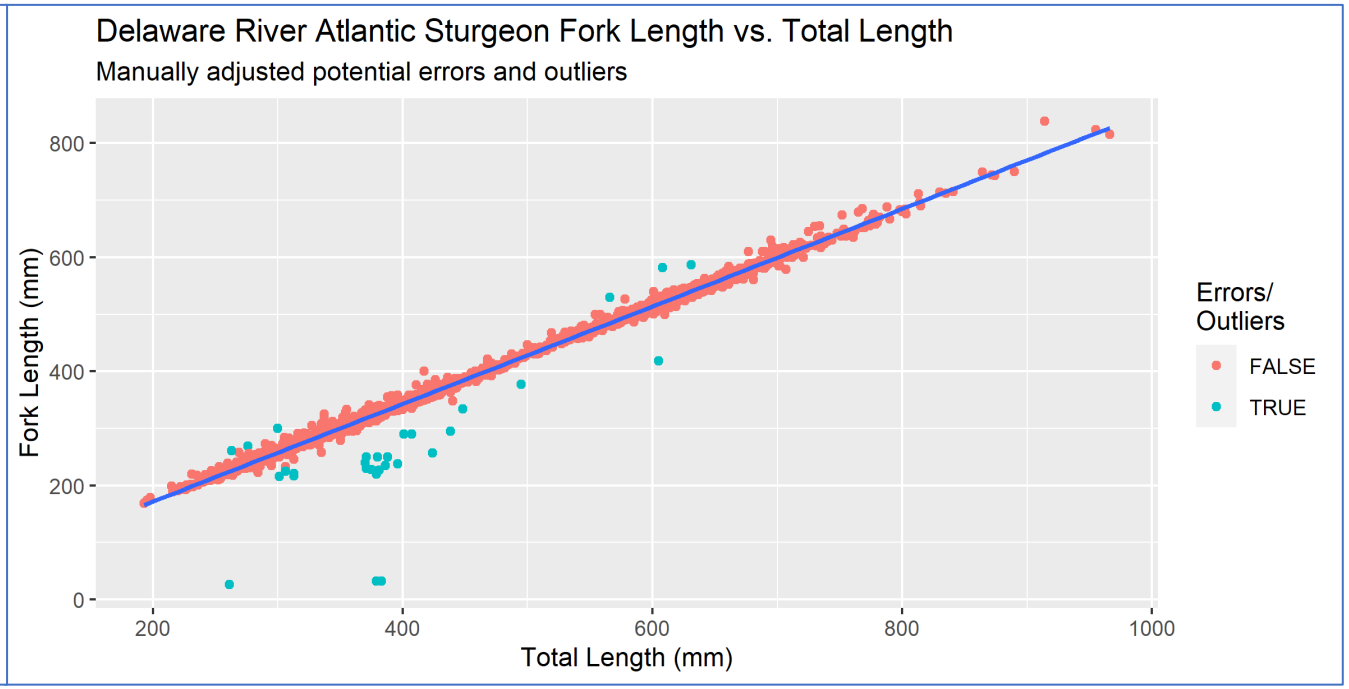
Sturgeon Data Processing

- Preliminary screening/flagging for errors and outliers (in R)
  - Missing values for total length, fork length or weight
  - Low or high outlier values for total length, fork length or weight
  - Missing or duplicate PIT tag ID
    - Some fish may have been too small to implant PIT tag (or other tag types)
    - Duplicate PIT tag records may indicate re-capture (within or across data sources)
  - Fork length > total length
  - Duplicate records w/same date, PIT tag & biometric data
  - Multiple records w/identical combinations of all three biometric factors (ERC)
  - Biometric (multivariate) outlier stats and visual screening
    - Fork length : total length ratio
    - Weight : total length or weight : fork length ratio
- QA/QC screening flags are preliminary and need fisheries expertise

Outlier Screening – Fork length vs. Total Length

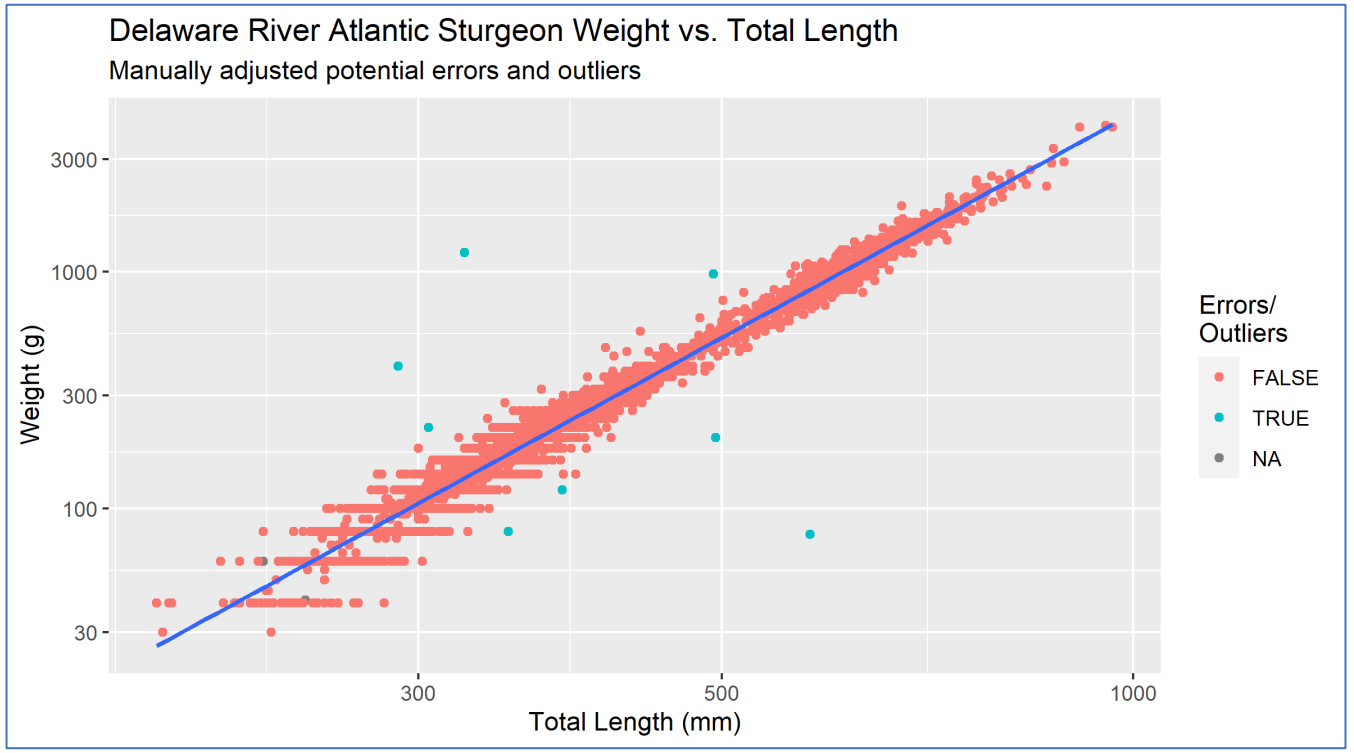
- Initial Cook's distance analysis (4/n) flagging, also residuals & Mahalanobis dist.
- Manually adjusted flags for high leverage values at low and high range of the data
- Subjective process, could be done differently; Can analyze with and w/o outliers





Outlier Screening – Weight vs. Total Length

- Data are heteroscedastic, exacerbated by imprecise weight measurements
- Subjective process, could be done differently; Can analyze with and w/o outliers



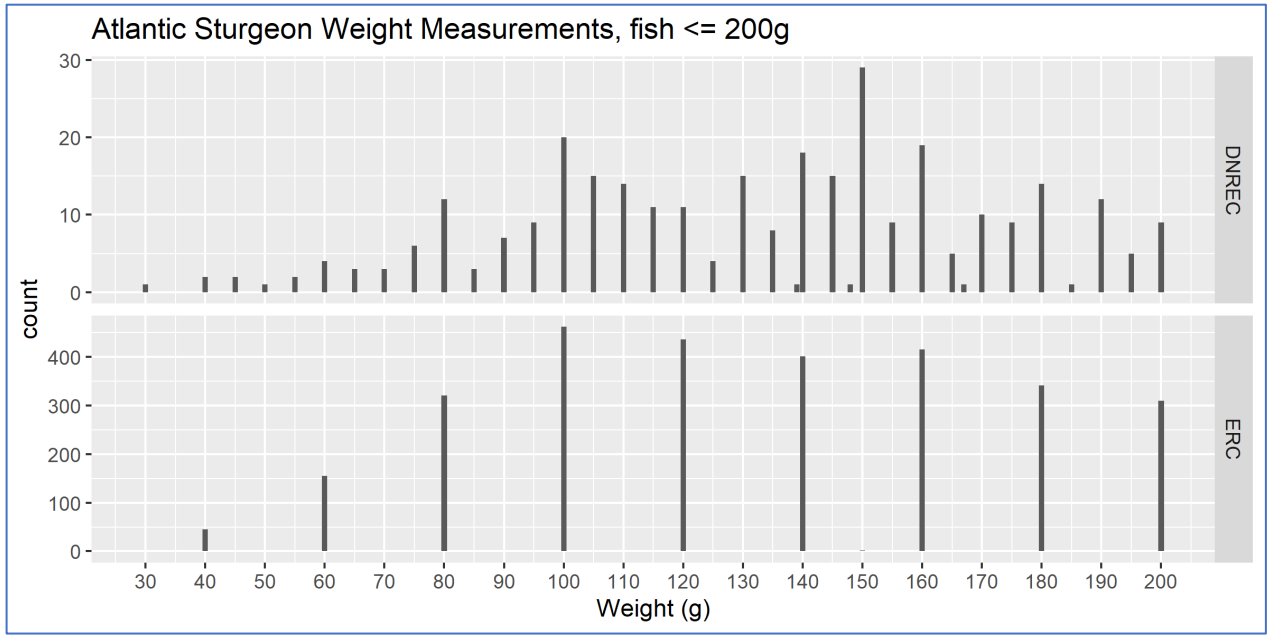
Preliminary Data Screening/Characterization

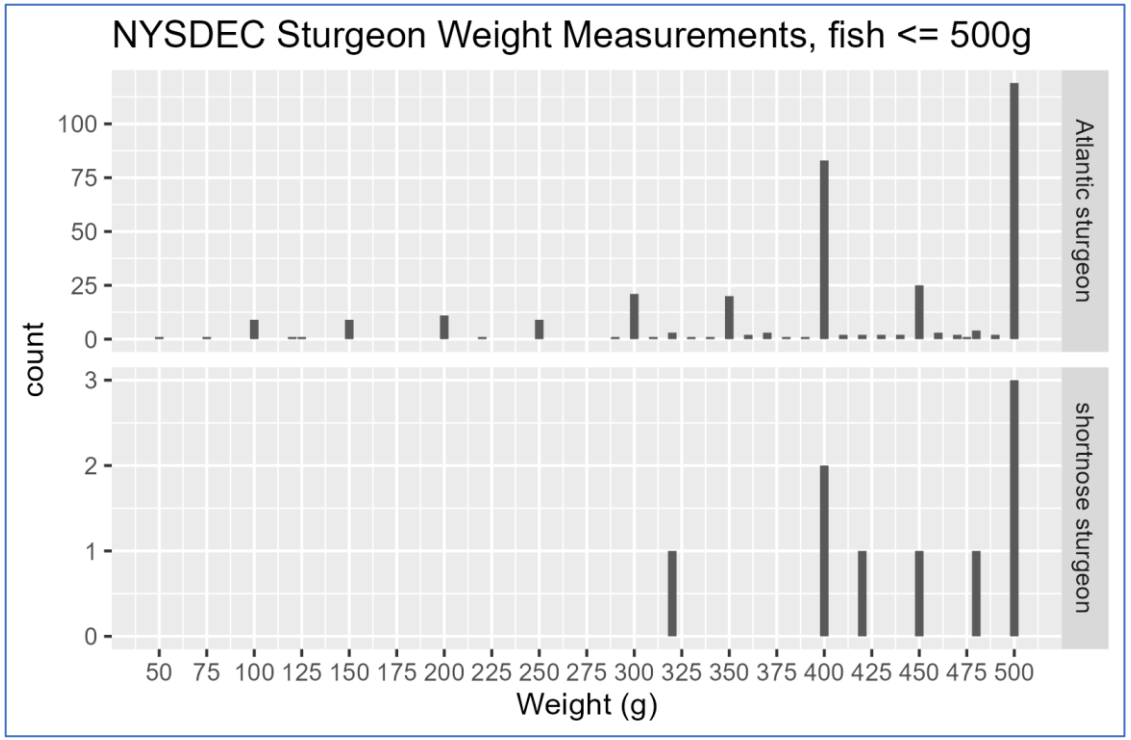
- Delaware sampling conducted outside growing season, Hudson more variable
- Fisheries expertise needed to understand implications for DO analysis

Agency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DNREC										63	197	138
ERC	483	1467	542								1179	1352
NYSDEC		48	1515	2895	325					224	176	44
HRG	19	24	29	42	16	28	227	220	182	175	272	91
Total	**502**	**1539**	**2086**	**2937**	**341**	**28**	**227**	**220**	**182**	**462**	**1824**	**1625**

Preliminary Data Screening/Characterization

- Length measurements very precise (nearest mm), weight relatively imprecise (~5, 20, 50g increments), Especially affecting small fish



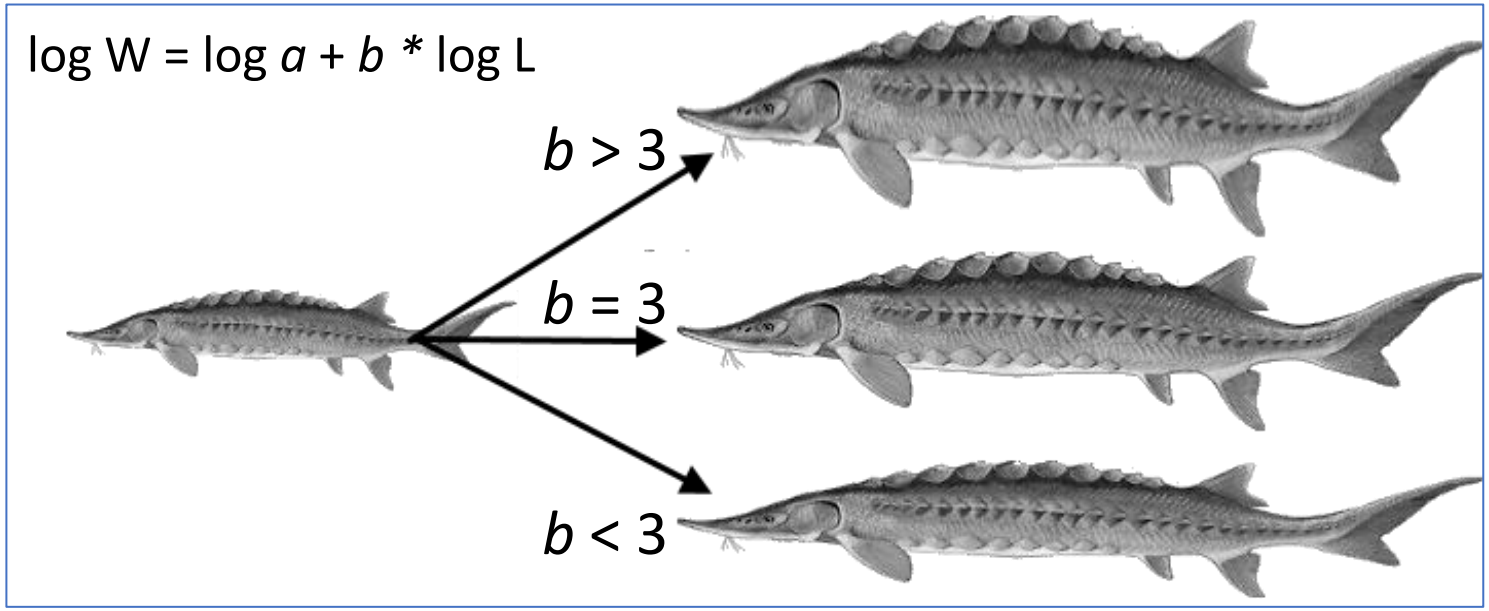


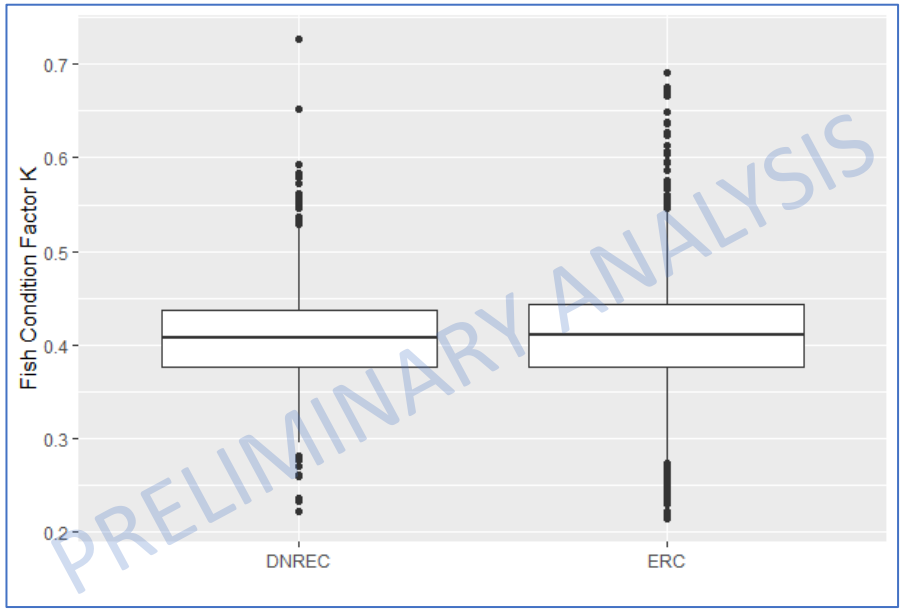
Tag-Recapture Data Screening/Analysis

- Recaptures identified by PIT tag and sample date
- Approx. 250 recapture events in combined Delaware data set
- Most recaptures occurred over relatively short intervals
- Most recapture intervals were at low temperature, outside primary growing season; low growth rates expected in winter
- Combining imprecise weight measurements with short recapture intervals can result in spurious growth rate estimates
  - Potential handling/relocation effects
  - Described in detail in NOAA NMFS Biological Opinion Reports
- Juvenile sturgeon reflect Delaware estuary conditions; larger fish range into ocean, potentially other estuaries (or may be from other DPS)

Weight : Length Data Screening/Analysis

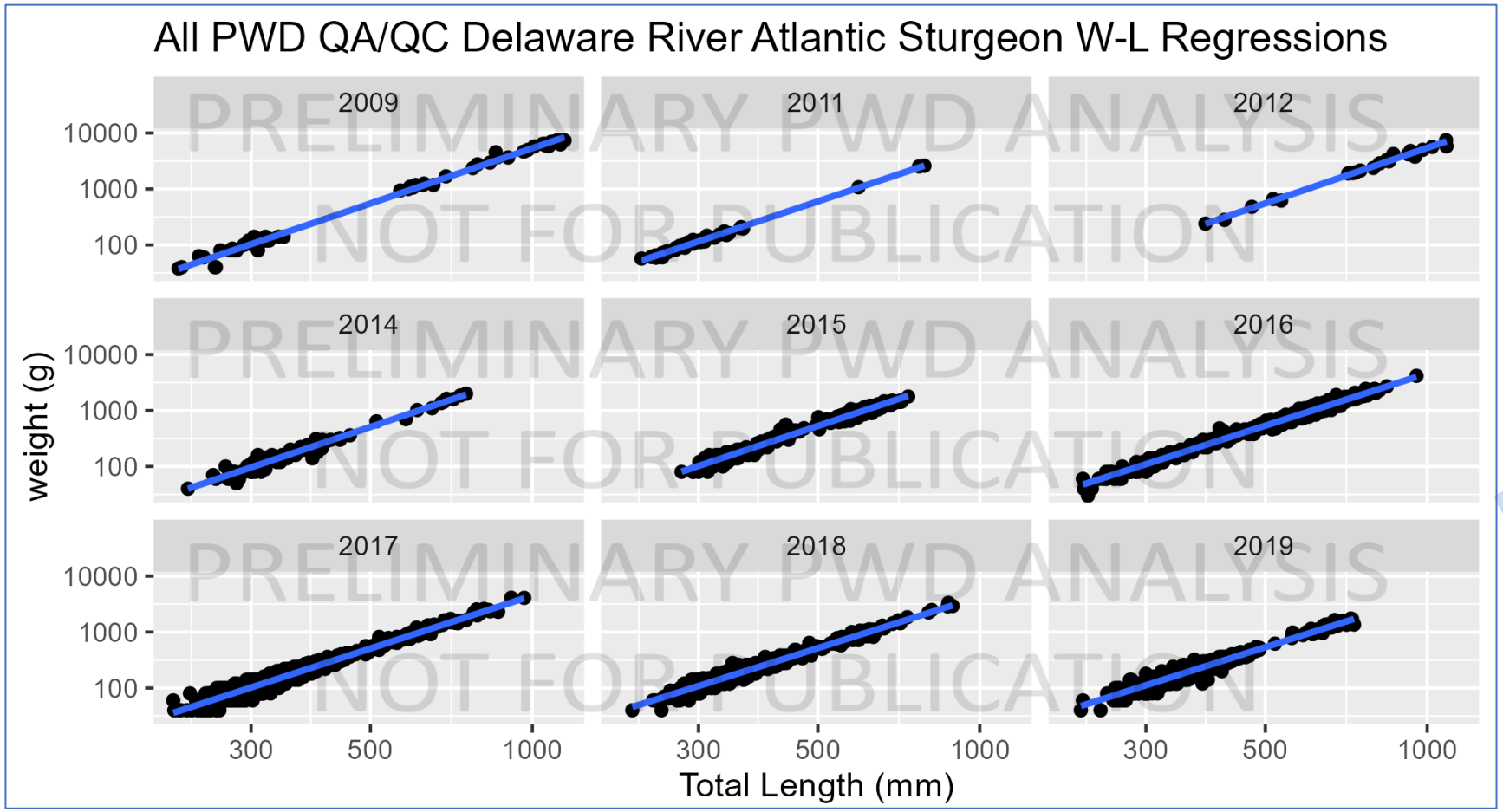
- Individual fish “condition factor” (Fulton’s K); measures plumpness
  - condition factor K = 100000 (W/L^3)
- Slope parameter *b* from W-L linear regression models of fish samples
- Both are confounded by imprecise weight measurements for small fish





Total Length K for Delaware River Atlantic sturgeon

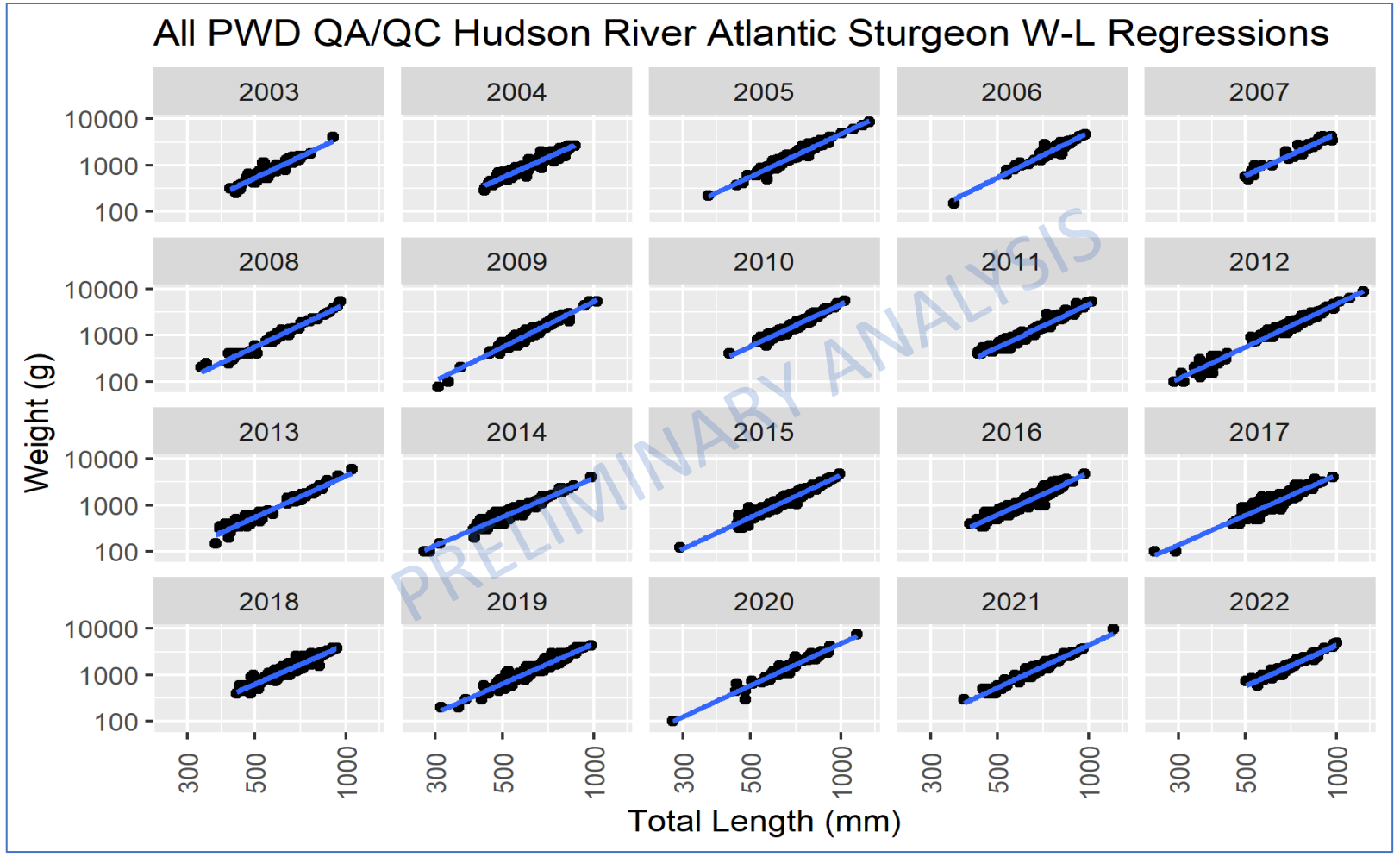
Delaware Atlantic Sturgeon W-L Regression



Year	n	*b* estimate
2009	52	3.28
2011	52	3.23
2012*	22	3.29
2013*	9	NA
2014	85	3.26
2015	408	3.22
2016	540	3.11
2017	1937	3.14
2018	950	3.05
2019	1366	3.07

*NOTE: small number of captures in 2012-2013 due to low sampling effort, **NOT** indicative of low abundance

Hudson Atlantic Sturgeon W-L Regression



Year	n	*b* estimate
2003	118	3.09
2004	190	2.92
2005	232	3.08
2006	69	3.25
2007	38	3.02
2008	64	3.11
2009	193	3.27
2010	191	3.04
2011	159	3.09
2012	242	3.09
2013	115	2.98
2014	337	2.78
2015	541	3.05
2016	359	2.99
2017	332	2.89
2018	572	2.85
2019	330	2.87
2020	98	3.03
2021	161	3.04
2022	107	2.92

Delaware DO Analysis

- Daily value statistics – Annual mean, median and minimum DO
- Instantaneous value statistics - 1st, 2nd, 5th, 10th percentiles; percent of data greater than 50%, 60%, and 70% DO saturation

			Growing Season			Critical DO Period		
ID	Station Name	year	mean	median	minimum	mean	median	minimum
1467200	Ben Franklin/ISM	2012*	69	70	40	58	57	40
1467200	Ben Franklin/ISM	2013*	72	70	44	67	65	44
1467200	Ben Franklin/ISM	2014	76	75	52	72	67	52
1467200	Ben Franklin/ISM	2015	74	73	49	72	67	49
1467200	Ben Franklin/ISM	2016	67	67	44	63	64	44
1467200	Ben Franklin/ISM	2017	74	71	56	69	68	56
1467200	Ben Franklin/ISM	2018	78	79	48	75	78	48
1467200	Ben Franklin/ISM	2019	71	71	49	66	65	49
1477050	Chester	2012*	69	66	44	64	64	44
1477050	Chester	2013*	76	74	58	75	72	58
1477050	Chester	2014	76	75	37	69	69	37
1477050	Chester	2015	76	76	43	74	73	46
1477050	Chester	2016	75	76	52	76	77	52
1477050	Chester	2017	79	77	54	74	73	54
1477050	Chester	2018	81	80	59	77	77	59
1477050	Chester	2019	77	76	41	70	67	41

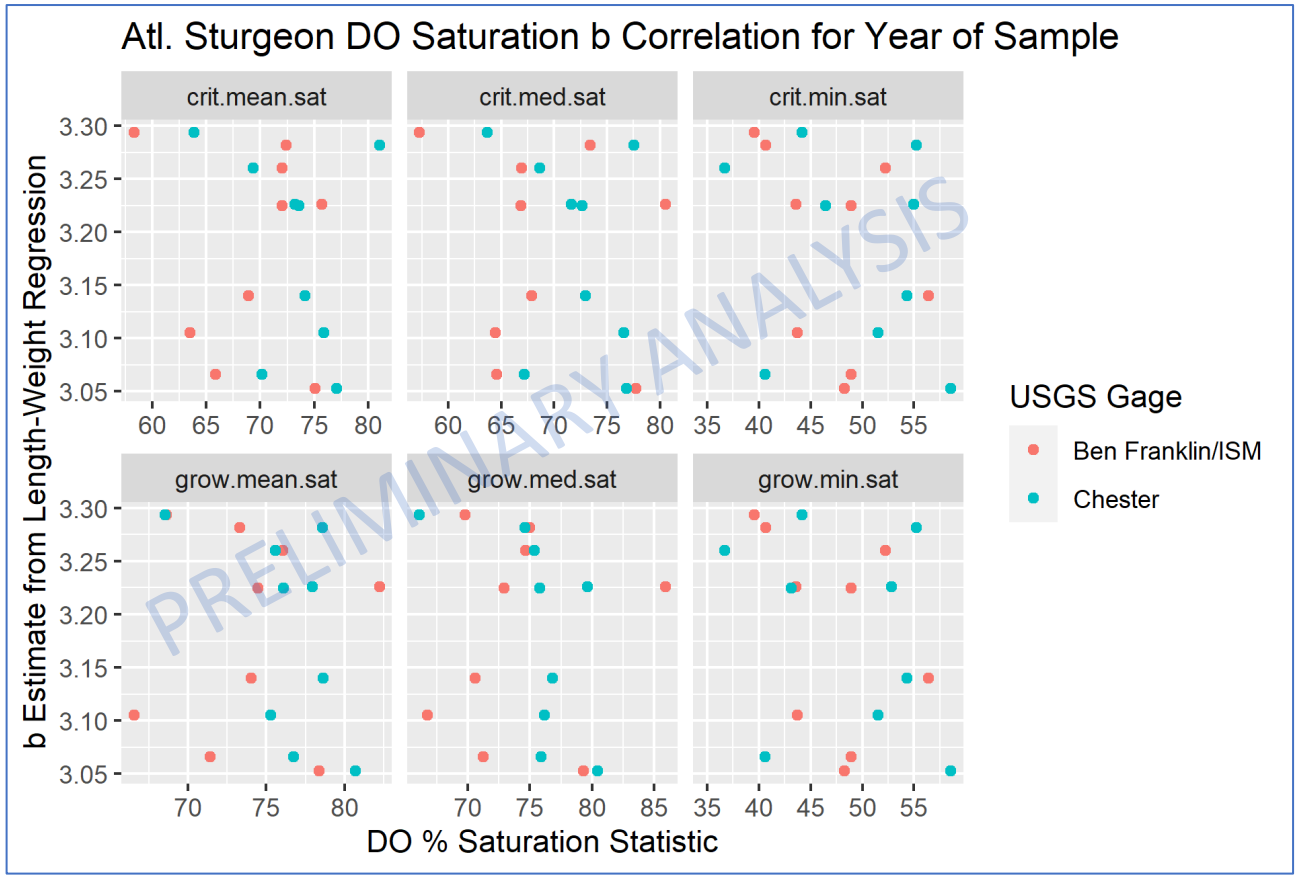
* Very few sturgeon specimens were collected from the Delaware River in 2012 and 2013. DO statistics included for comparison purposes

Delaware DO Analysis

		Growing Season							Critical DO Period						
ID	year	10th pctile	5th pctile	2nd pctile	1st pctile	Pct > 70%	Pct > 60%	Pct > 50%	10th pctile	5th pctile	2nd pctile	1st pctile	Pct > 70%	Pct > 60%	Pct > 50%
1467200	2012*	51	49	46	44	50	68	93	49	47	44	43	11	37	85
1467200	2013*	59	57	55	53	52	87	100	57	55	53	52	35	77	100
1467200	2014	62	60	58	57	62	94	100	60	58	57	56	42	89	100
1467200	2015	61	59	56	55	62	93	100	59	57	55	53	44	88	100
1467200	2016	56	52	49	48	32	80	96	54	51	49	48	16	69	96
1467200	2017	63	62	60	60	59	98	100	62	60	60	59	39	97	100
1467200	2018	66	63	58	55	79	97	100	63	59	55	54	74	94	100
1467200	2019	58	55	53	52	55	86	99	56	54	52	51	29	75	99
1477050	2012*	58	56	53	52	33	79	96	56	54	52	50	13	75	99
1477050	2013*	66	64	61	60	71	95	96	66	64	61	60	66	96	97
1477050	2014	63	59	55	52	70	94	99	60	56	52	49	46	88	98
1477050	2015	65	61	55	52	75	94	98	64	62	58	56	68	96	99
1477050	2016	67	65	63	62	77	100	100	67	65	63	61	80	99	100
1477050	2017	68	66	63	61	82	99	100	66	64	61	60	71	99	100
1477050	2018	72	70	67	66	94	100	100	70	68	66	65	89	100	100
1477050	2019	61	57	53	51	65	91	99	57	54	51	49	44	82	99

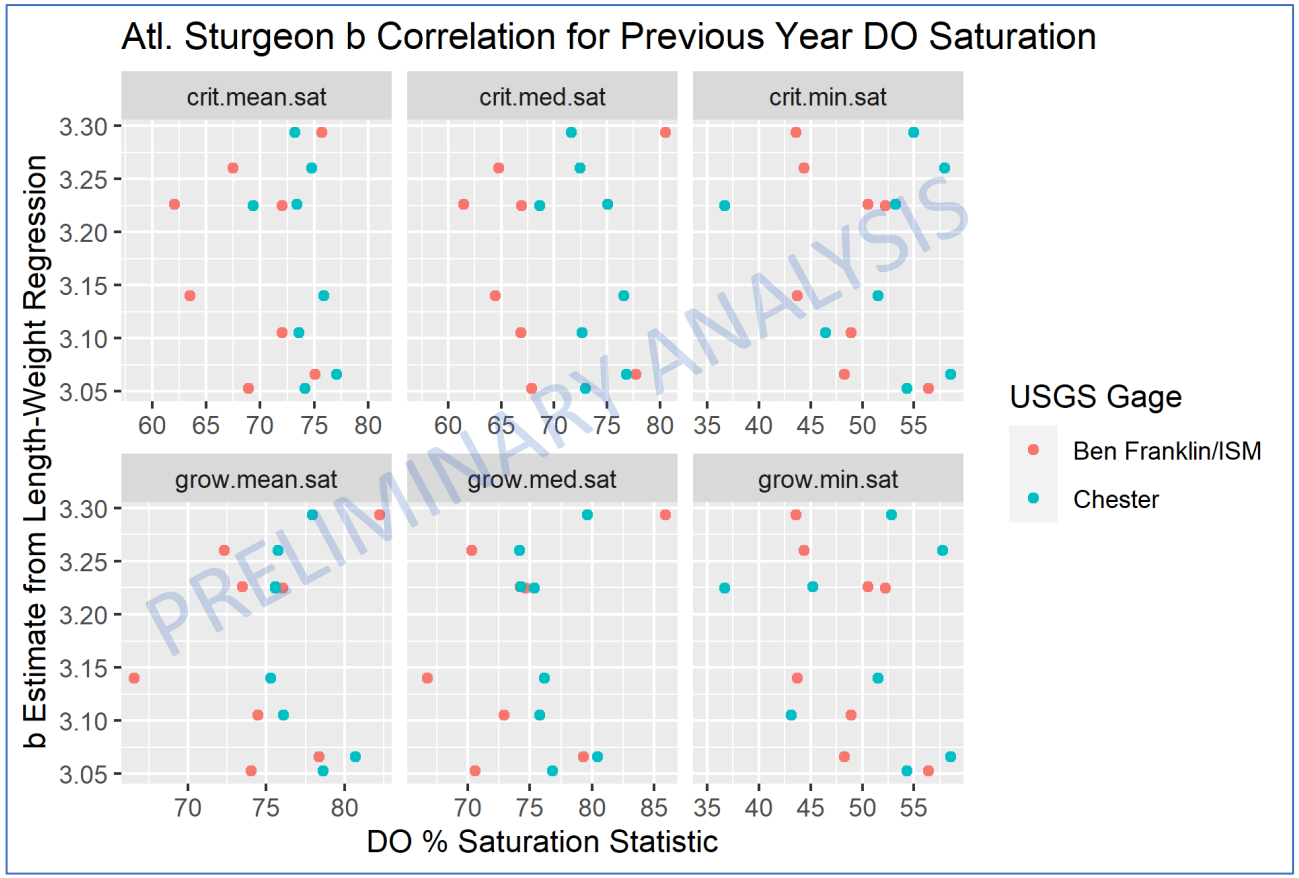
* Very few sturgeon specimens were collected from the Delaware River in 2012 and 2013 due to lack/low sampling effort. DO statistics included for comparison purposes

Delaware Atlantic Sturgeon *b* Estimates vs. DO



Station	DO Statistic	cor	p
1467200	Critical Period Mean DO Sat	-0.05	0.912
1467200	Critical Period Median DO Sat	-0.12	0.776
1467200	Critical Period Min DO Sat	-0.46	0.213
1467200	Growing Season Mean DO Sat	-0.083	0.843
1467200	Growing Season Median DO Sat	0.017	0.982
1467200	Growing Season Min DO Sat	-0.46	0.213
1477050	Critical Period Mean DO Sat	-0.37	0.336
1477050	Critical Period Median DO Sat	-0.28	0.463
1477050	Critical Period Min DO Sat	-0.22	0.581
1477050	Growing Season Mean DO Sat	-0.43	0.25
1477050	Growing Season Median DO Sat	-0.77	0.0214
1477050	Growing Season Min DO Sat	-0.18	0.644

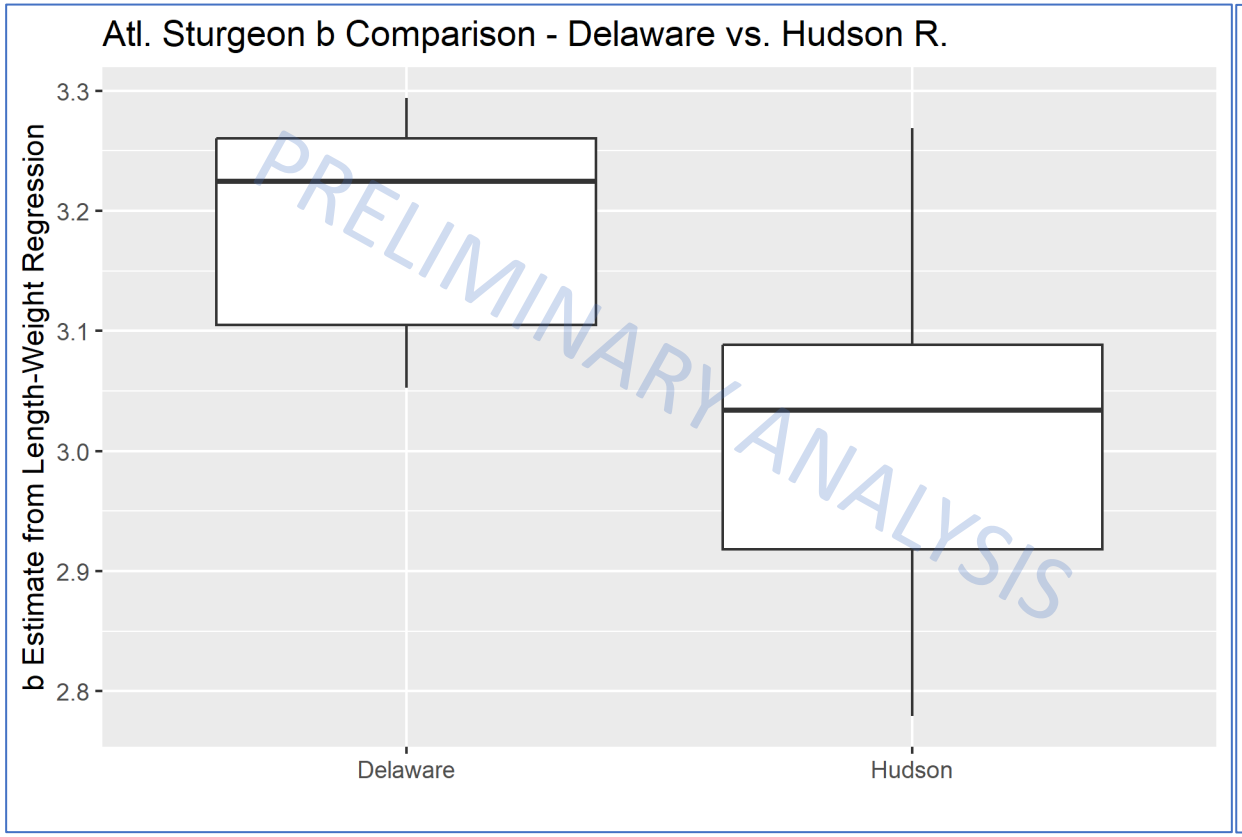
Del. Atlantic Sturgeon *b* Estimates vs. lagged DO

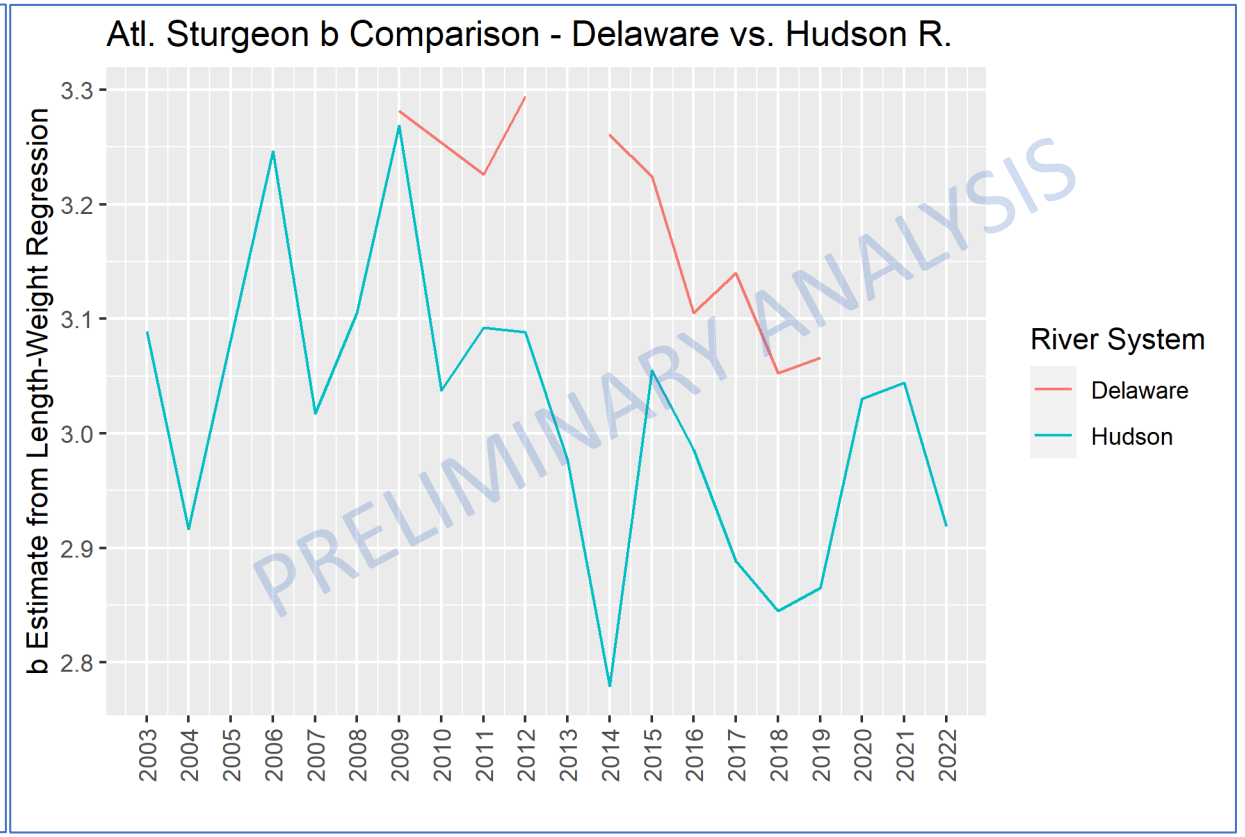


Station	DO Statistic	cor	p
1467200	Critical Period Mean DO Sat	0	1
1467200	Critical Period Median DO Sat	-0.14	0.752
1467200	Critical Period Min DO Sat	-0.55	0.171
1467200	Growing Season Mean DO Sat	0.024	0.977
1467200	Growing Season Median DO Sat	0.21	0.619
1467200	Growing Season Min DO Sat	-0.55	0.171
1477050	Critical Period Mean DO Sat	-0.48	0.243
1477050	Critical Period Median DO Sat	-0.55	0.171
1477050	Critical Period Min DO Sat	0.071	0.882
1477050	Growing Season Mean DO Sat	-0.38	0.36
1477050	Growing Season Median DO Sat	-0.43	0.299
1477050	Growing Season Min DO Sat	-0.14	0.752

Del Atl. Sturgeon *b* vs NYSDEC Hudson R.

- Delaware River 2009-2019 had significantly higher *b* estimates from W-L regression than Hudson R. 2003-2022 (Wilcoxon test W = 156, p = 0.0011)





Preliminary Conclusions & Important Caveats

- Atlantic sturgeon appeared to spawn successfully in the Delaware each year monitored, though insufficient data for critical DO years 2012-2013
- Recent years with expanded sampling effort yielded hundreds or thousands of juvenile sturgeon specimens
- W-L relation slope estimates for Delaware juvenile sturgeon
  - In normal range for species, median $b > 3.2$
    - Some evidence for decreasing trend, but large differences in sample size
  - Did not vary consistently with measures of DO saturation for years analyzed
  - Relatively higher than Hudson R. sturgeons sampled by NYSDEC
    - Additional Hudson R. background information needed to determine if comparisons between river systems are appropriate

Wrap-Up

- All analyses presented today are **preliminary and subject to revision**
- Additional data quality checks and DO – sturgeon analysis
  - Hudson R. daily value (DV) DO stats
  - Delaware and Hudson R. instantaneous DO stats
  - Hudson River Generators sturgeon data analysis
  - DO – fish condition factor correlation analysis
- Solicitation of fisheries expertise
  - Improve/validate PWD preliminary QA/QC and outlier screening
  - Group/analyze fish by age class cohorts
- Future monitoring and potential coordination with discharger group
  - PWD sidestream treatment and other potential projects

Thank You!

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